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14. ABSTRACT

This report describes the research performed on behalf of the Office of Naval Research (grant #N00014-03-1-0393) to estimation of refractivity profiles from radar clutter returned. Through simulation and experimental results it is shown that the radar clutter return can be used for extracting refractivity profiles. Of particular interest is the uncertainty in these estimates and it is demonstrated how these parameters can be used for radar performance prediction.

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Bayesian Inversion of Radar Clutter

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Abstract
Estimation of refractivity profiles from radar clutter return is discussed. Through simulation and experimental results it is shown that the radar clutter return can be used for extracting refractivity profiles. Of particular interest is the uncertainty in these estimates and it is demonstrated how these parameters can be used for radar performance prediction.

Research Summary

The goal of this project was to develop inversion approaches that enable the estimation of refractivity profiles and the associated uncertainty. Further to develop methods for mapping the refractivity parameters and their associated uncertainty into propagation.

The results of this reseach are documented in five refered jornal papers [1-6] and one conference proceeding [7].

Our inversion approach has mainly been based on SAGA and focused on estimation of the parameters corresponding to the field that gives the best fit to the data. We have concentrated on demonstrating the feasibility of RFC using an efficient 11-parameter description of the environment. The quality of the inversion was addressed by comparing the field using the estimated parameters to a measured field [1-6]. Little has been done to indicate the quality of the solution for each parameter, either with the variance of parameter-estimate or preferably the complete *a posteriori* distribution. We have already done much work on this in an ocean acoustic context [Gerstoft 98], but this has not been explored in

our RFC processing to date. This entails developing likelihood formulations and importance sampling algorithms. This inversion approach shows the information content in the data, the importance of each parameter, and the quality of the inversions [1-2].

The simulated data are generated based on the helicopter measured range-dependent refractivity profiles (Run 7) for the Wallops 98 experiment [Gerstoft03a], see Fig 1. A range interval from 10-100 km is used. A simple trilinear model (Fig 2) is used for the inversion of the refractivity profile as outlined in the Appendix of [Gerstoft03a]. We then search for tri-linear refractivity parameters at 0 and 100 km range. To obtain refractivity profiles at other ranges the parameters are interpolated linearly. The first 3 parameters were given a uniform distribution but the slope was given a non-uniform distribution as indicated in Fig 3 (left bottom). This is because a negative mixed layer slope is only likely for shallow ducts (low base height).

First, 90,000 environmental models are selected from the prior distributions, Fig 3 left. Using these environmental models, 90,000 vectors of propagation loss versus range are precomputed. The posteriori distribution (right column Fig. 3) is computed as a product of the prior distributions with the likelihood distribution. The likelihood distribution shows how well the environmental models describe the data. We note that the overall behavior of the posteriori distributions seems reasonable.

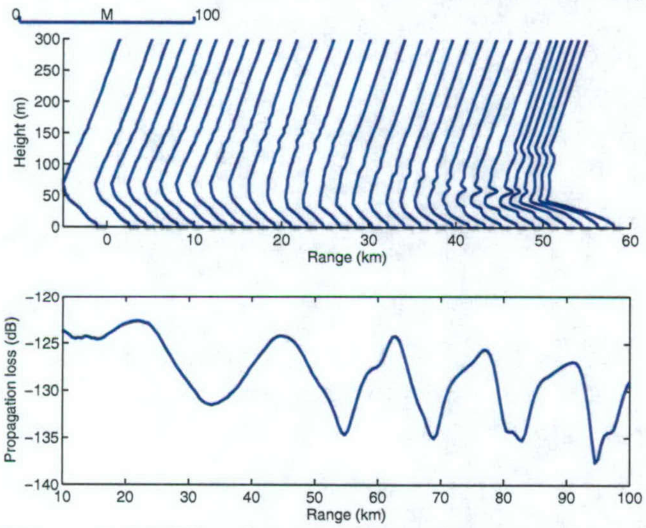

Figure 1 (a) The observed refractivity profile and (b) the simulated propagation loss data.

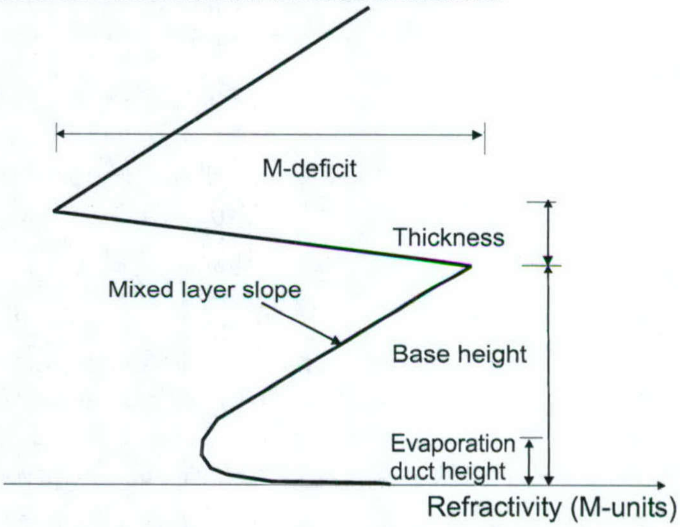

Figure 2 Trilinear model. We invert for the base height, thickness, M-deficit and the mixed layer slope.

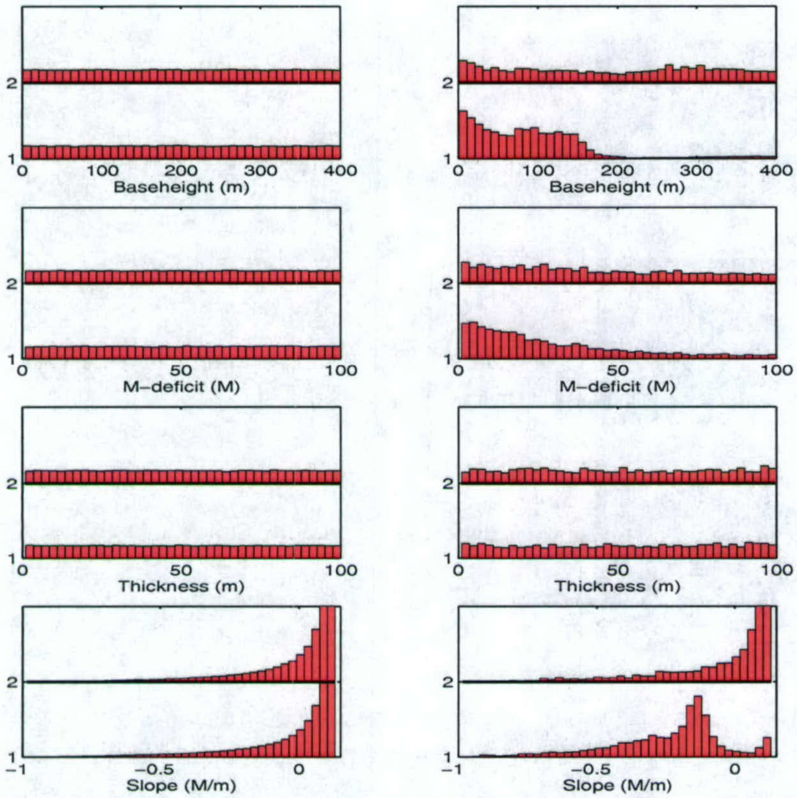

Figure 3 Prior (left) and posteriori (right) distributions of the parameter estimates. The abscissa "1" (lower panel) and "2"(upper panel) refers to the values at emitter and receiver, respectively.

The overall objective is to estimate posteriori statistics of propagation loss. An example of this is shown in Fig 4. We compute the average priori propagation loss based on an even weighting of the propagation loss from each generated refractivity model. The posteriori probability distribution of the propagation loss is based on weighting the propagation loss from each refractivity model with the posteriori probability.

The average prior and posteriori propagation losses are shown in Fig. 4b and c. It is seen that the average posteriori propagation loss identifies a ducting environment as observed in the data, Fig. 4a, but the prior does not.

The probability distribution of the propagation loss then is computed at all ranges and depths. Both prior (Fig. 5 left) and posteriori (Fig. 5 right) propagation loss are shown at 10 and 100 m height as a function of range. Clearly, the posteriori plot shows how the data has improved our estimation of propagation loss.

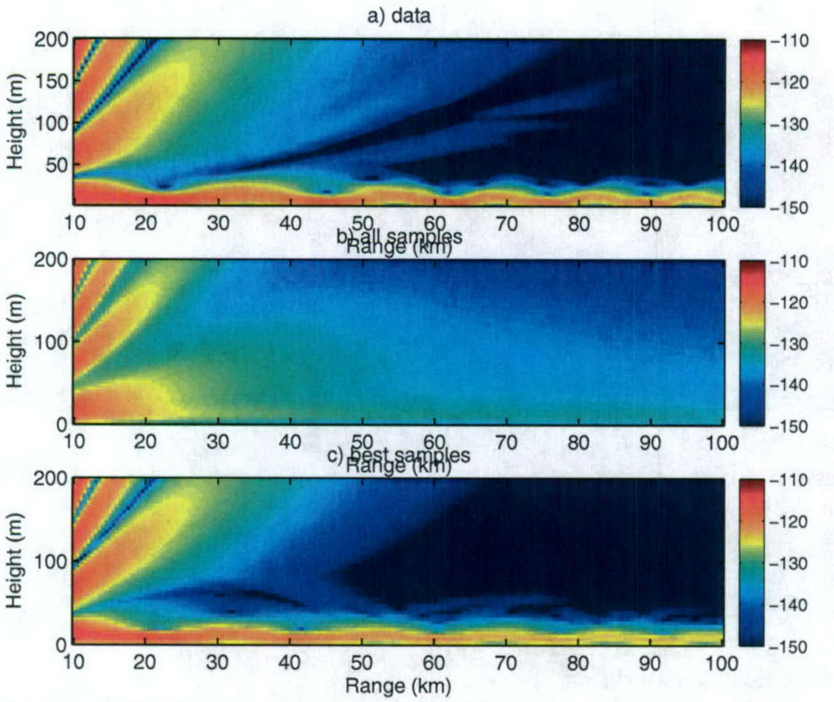

Figure 4: (a) The propagation-loss field from the true environment (from Fig. 1a) and the average propagation-loss field based on (b) prior information, and (c) posteriori information (bottom).

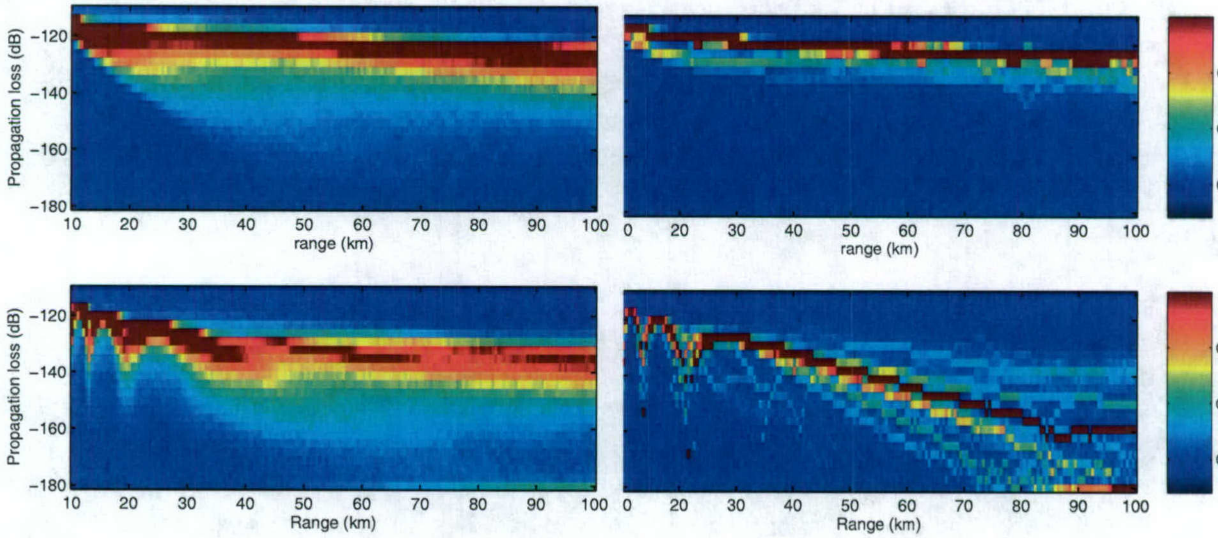

Figure 5 Prior (left) and posteriori (right) propagation loss probability distributions at 10 m (top) and 100 m (bottom).

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